Characteristics of Seismicity Distribution along the Sunda Arc: Some New Observations

GHOSE, Ranajit; OIKE, Kazuo

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By Ranajit GHOSE and Kazuo OIKE

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Abstract

Spatio-temporal variations of earthquake activity along the Sunda arc were investigated. We prepared a strain release map for this century. Adjacent to the zones of high strain release, presence of seismically quiet zones was noted. A careful inspection of the depth distribution of the earthquakes revealed that in the eastern Sunda arc, possibly there exists a zone of scarce seismicity at an intermediate depth. We discussed the probable implications. We also analysed the patterns of temporal distributions of earthquakes at the three different seismotectonic provinces of the Sunda arc—Sumatra, Java, and the Lesser Sunda Islands. We could clearly see that, although the causative geodynamic situations for seismicity vary significantly in space along the length of the arc, the period of increase or decrease in seismicity is largely space invariant. The locally differing levels of seismicity are superposed on the common background of long period seismicity fluctuation. Finally, clustering of seismicity at some patches along the Sunda arc was studied with respect to the altimetric gravity anomaly data. We noted some apparent conformities. For some of our present observations, there exists much scope for detailed future investigations, which we discussed.

Introduction

We analyzed the seismicity data along the entire stretch of the Sunda arc which is unfurled in the southeast Asean region between Andaman-Nicobar Islands in the northwest and Banda arc in the east. The total length of the arc is over 5600 km and it represents all the features of a typical island arc where an oceanic plate (here the Indian Ocean-Australian plate) subducts below a continental plate (here the southeast Asean flank of the Eurasian plate). Either in a local scale or regionally, the nature of distribution of earthquakes, volcanoes, gravity and magnetic anomalies, petrology, geochronology and palaeomagnetism of rock samples, crustal seismic velocity structures determined using artificial and/or natural seismic sources, as well as the focal mechanisms of earthquakes and the derived stress distribution in the descending oceanic slab and adjacent regions have been investigated and reported by many researchers, references of any or all of which we refrain from citing here for the sake of brevity. Recently, Newcomb and McCann (1987)[1] has reported of the seismic history of the Sunda arc region.

Fig. 1 shows the plate tectonic setting and bathymetry of the Sunda arc region. Many of the morphologic and geodynamic features of the Sunda arc change significantly along its strike. Minster and Jordan's (1978)[2] RM2 model proposed a plate convergence rate of 6 cm/yr near the northern tip of Sumatra to 7.8 cm/yr near Sumba in the east. The age of the youngest oceanic crust subducting at Sumatra is 46

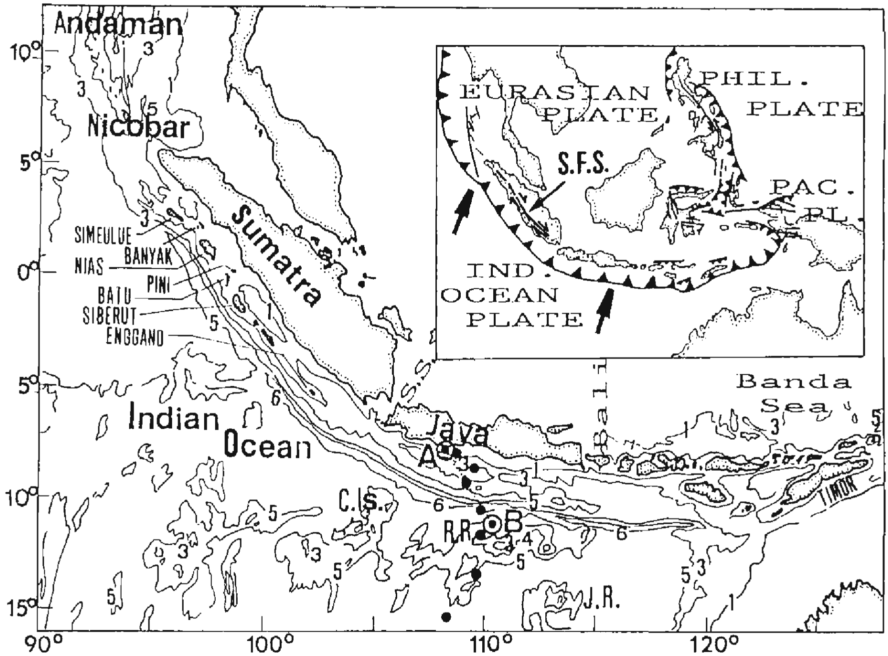

Fig. 1, Plate tectonic setting and bathymetry in the Sunda arc region (modified after Newcomb and McCann, 1987[1]). Black dots denote the sesimic refraction profile of Curray et al. (1977)[8]. The fine dotted line shows one seismic reflection profile from Newcomb and Mccann (1987). S.F.S. stands for Sumatra Fault System. C. IS., R.R., and J.R. are Christmas Island, Roo Rise and Joey Rise respectively. The bathymetric contours are in km.

Ma while the oldest oceanic crust near Java and Lesser Sunda Islands is 152 Ma old. The major morphostructural units can be recognised all along the margin of Sumatra and Java. Fore arc geometry systematically varies from west to east (the depth of the fore arc basins, the trench slope break and the trench increase towards Java) as the sediment thickness on the subducting oceanic plate decreases. A relatively simple style of subduction occurs where the oceanic crust is subducted beneath the continental platform of Sumatra and western Java as well as the island arc of eastern Java and the western Lesser Sunda Islands (Newcomb and McCann, 1987)[1]. More complex tectonic systems exist in the Andaman Islands, where convergence is essentially subparallel to the arc (Curray et al., 1978)[3], and east of Java, where collision of the island arc of the Lesser Sunda Islands and the Australian continent occurs (Silver et al., 1983)[4].

Sunda Strait, which separates Sumatra from Java serves as a major boundary between two different geodynamic regimes. The trench itself is curved landward west of the Sunda Strait, so that the Strait appears to be a transition zone between two different regions (Budiarto, 1976[5]; Ranneft, 1979[6]; Zen, 1983[7]). An abrupt change in the depth of penetration of the Benioff zone between east and west of the Strait is very significant. West of Sunda Strait the seismic activity does not exceed below 200 km, while in the east there is a sudden increase in the maximum depth of seismicity to 650 km with a gap between 300 and 500 km. Le Pichon and Hiertzler (1968)[9], Fitch (1970)[10], and Fitch and Molner (1970)[11] discussed the possible explanations for this; however for lack of further substancial evidences equivocality still remains. Interplate motion, normal to the island arc near Java, becomes oblique at Sumatra, where motion parallel to the arc is accomodated by dextral strike-slip displacement along the 1600 km long Sumatra (also known as Semangko or Bati) Fault System, shown in **Fig. 1** (for details, refer to Fitch, 1972[12]; Katili, 1974[13]; Tija, 1978[14]; Curray et al., 1978[3]; Huchon and Le Pichon, 1984[15], among others).

With this background knowledge and using updated data base we assessed the seismicity in the whole of the Sunda arc region. Spatio-temporal variation in earthquake activity was investigated. In order to obtain an insight into the process of how the heterogeneity in the horizontal compressive stress (coupling) between plates across the subduction boundary is related to the local or regional morphologic or tectonic features, we prepared a regional strain release map, using earthquake data of this century. A careful reinspection of the depth distribution of earthquakes revealed some hitherto unreported peculiarities. We also noticed a remarkable resemblance in the patterns of temporal variations of seismicity in the three different seismotectonic provinces of the Sunda arc—Sumatra, Java and the Lesser Sunda Islands. It clearly shows that although the causative geodynamic situations for seismicity vary significantly in space, for the entire Sunda convergence zone, the period of increase or decrease in seismic activity is lagely space invariant. As if, the varying local levels of seismicity are superposed on a common background of long period seismicity fluctuation. Further to these observations, clustering of seismicity at some patches along the Sunda arc has been studied with respect to the gravity anomaly data extracted from the satellite altimetry. Some interesting conformities could be noticed. In this paper, we report of all these observations, and discussed some probable implications. It is expected that enhanced understanding in spatial and temporal changes in seismic activity along the Sunda arc will also provide a better background to identify the regional distinctive features of plate tectonics.

Data

The aim of our present study was to assess the spatial and temporal distribution of seismic activity along the Sunda arc. For this purpose we used two data bases, viz. the NOAA Hypocentre Data File (from Jan., 1900 to May, 1981) and the ISC Data File (from Jan., 1971 to Dec., 1983). The NOAA Hypocentre Data File includes all the earthquakes recorded by at least five stations. The coverage of the earthquake activity in this data file is somewhat uneven. Only the large events have been reported prior to 1922 because of poor seismographic coverage, while since 1961 most earthquakes with magnitude $\geqq 4.5$ are included. The completeness of the

NOAA hypocentre Data File was investigated by Perez and Scholz (1984)[16]. In order to ensure the possibility that data coverage is sufficient to identify temporal changes in seismicity, we used only large events with magnitude $\geqq 6$, for which the NOAA Data File, excepting possibly a few earlier years of this century, is more or less complete. For the large events we also consulted the recent catalogue of Newcomb and McCann (1987)[1], with some of the epicentres relocated. For examining the spatial distribution of earthquakes, in relation to volcanicity, bathymetry, and other tectonic and structural features, we used the ISC Data File. We used only those events located by 15 or more station reportings. Out of all hypocentral parameters, the depth estimates are perennially most unreliable. We accepted all the reported pP-P depth estimates to minimize any major depth bias. As the possibility of spurious identification of pwP phases as pP (resulting in deeper depths) still remains, we were careful to keep enough allowance for errors in depth estimates before reaching any conclusion based on them.

Seismicity and Regional Strain Release

In **Fig. 2a** and **2b** the earthquakes from respectively the NOAA and the ISC Data Files were plotted. The ISC events of **Fig. 2b** are those events which have been located by 25 or more station readings, and hence the epicentral locations are reliable. We can easily recognize some seismically more active patches.

We reanalysed the regional seismicity distribution with the background of the hitherto known facts. In Sumatra, the subduction process has a much younger history than Java and Lesser Sunda Islands, where the subducting oceanic crust is very old, and the slab has penetrated much deeper down, to generate some of the deepest earthquake events with downdip compressional mechanism. The shallowest earthquakes (0–20 km) immediately adjacent to the Sunda trench are commonly associated with strain release occurring within the subducted lithosphere. At Sumatra, the interplate seismic coupling is very high, and thus causes the large thrust events. The majority of strong earthquakes in both the historic and instrumental catalogues of the Sunda arc are located in the fore arc of Sumatra. While Nias and Enggano (shown in **Fig. 1**) were documented as the locus of activity in the historic record, moderate and large instrumentally recorded earthquakes group principally in central Sumatra, on the Pini Arch, and in southern Sumatra, at Enganno (Newcomb and McCann, 1987[1], and also visible in **Fig. 2c** here). The region near Enggano seems to have experienced a large earthquake every 27 years, on an average, since 1756. Besides the established evidence of seismicity related to the back arc thrusting north of flores, in recent years support continues to grow for the importance of back arc thrusting north of the Timor trough, along which the Australian continental crust is being subducted northward beneath the eastern Sunda arc (Silver et al., 1983[4]; McCaffrey et al., 1985[17]; McCaffrey and Nabělek, 1984[18], 1986[19]). Another recent explanation of a local seismicity has been presented by Spence (1986)[20] who argues

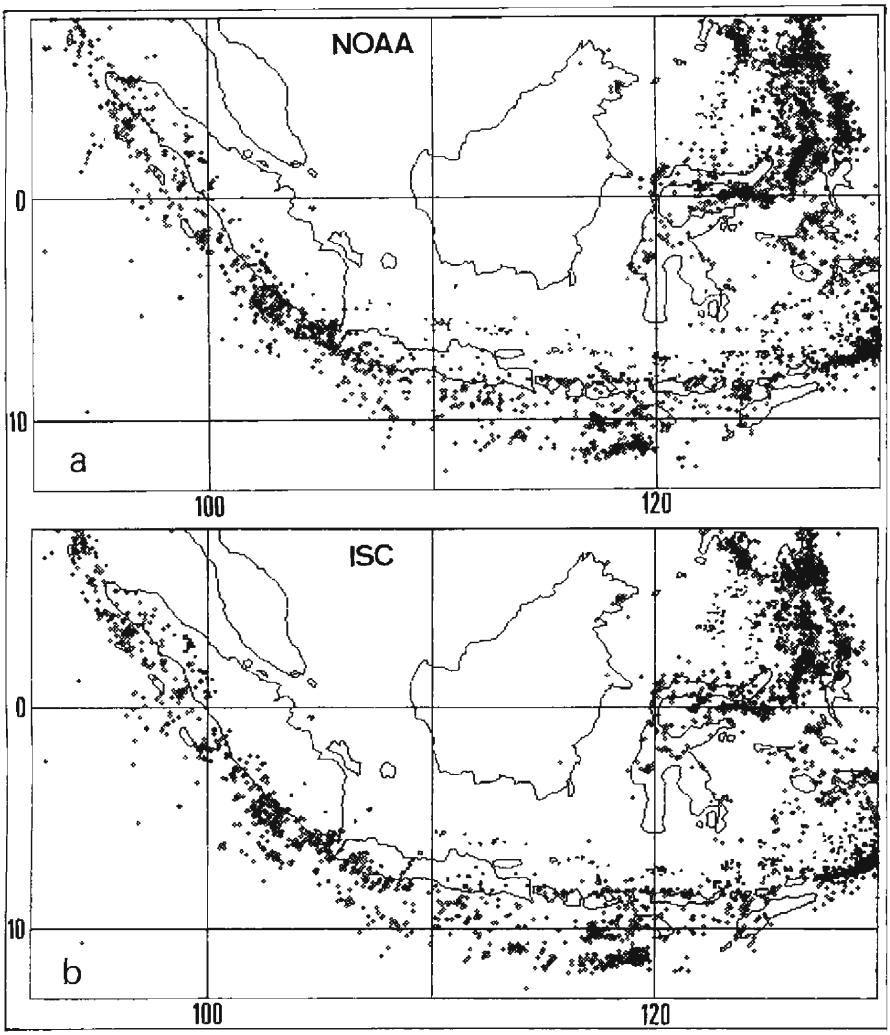

Fig. 2a. Distribution of earthquakes in the Sunda arc region during 1900–May, 1981, from NOAA Hypocentre Data File.
Fig. 2b. Distribution of earthquakes in the Sunda arc region during 1971–1983, located by 25 or more station readings, from ISC Data File.

that the great (M 7.9) Sumba earthquake of August 9, 1977, which is the largest normal faulting event to occur since the Sanriku event of 1933, supports slab-pull as the dominant process for subduction of the oceanic crust beneath the easternmost section of the Sunda trench.

In **Figs. 2a** and **2b** we can identify the localities with maximum earthquake frequencies. They are located at the northern tip of Sumatra, north of Simeulue island, southeast of Nias (near Pini), southern tip of Siberut island, near Enggano, southern end of Sumatra near Sunda Strait; and at Java and Lesser Sunda Islands,

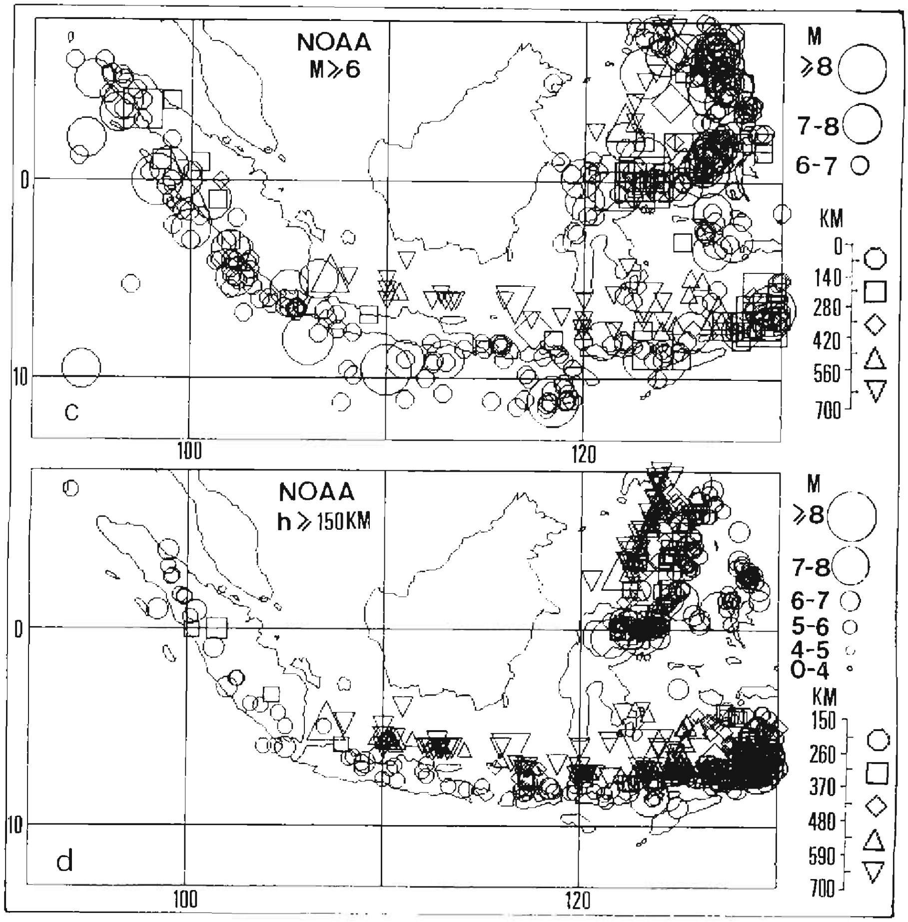

Fig. 2c. Distribution of large earthquakes with magnitude ≥6 in the Sunda arc region during 1900–May, 1981, from NOAA Data File.

Fig. 2d. Distribution of earthquakes deeper than 150 km in the Sunda arc region during 1900–May, 1981, from NOAA Data F le.

near the western tip of Java, south off Java around 107°E and 110°.5E, and southwest of Sumba (the region of locally enhanced slab-pull force). It is striking that at Sumatra, although the plates are strongly coupled, the shallow seismicity does not extend much into the continental platform, whereas whole of Java experiences many such shallow events. The difference in slab penetration between Sumatra and Java cannot completely account for this difference in shallow seismicity inlands of Sumatra and Java. On the basis of our observation, we suggest two possible factors. Newcomb and McCann (1987)[1] proposed seismic and aseismic modes of subduction for Sumatra and Java respectively. We speculate that as most of the interplate stress build-up is released right at the outer arc thrust zone for Sumatra, and as much of the seismicity observed inland Sumatra is caused by the movement of the Sumatra Fault System, there is possibly not much residual interplate stress related to subduction, left to be transmitted for causing the shallow events in the overriding plate, north of the volcanic front. In contrary, in case of a decoupled arc segment like Java, although the interplate stress accumulation is less, the stress release in the thrust zone is also relatively much less. As a result, the net residual stress transmitted to the continental side might be greater in the decoupled portion (Java) than in the coupled one (Sumatra). Secondly, the distance from the trench to inland Sumatra exceeds that to Java. As a matter of fact, the line of active volcanoes (which usually corresponds to the 100 km depth contour for the inclined seismic zone, notable in **Fig. 4**) passes through the centre (E–W) of Java, whereas for Sumatra it runs close to the Indian ocean coast. This also contributes to the greater seismic activity in the shallow continental part north of Java, compared to Sumatra.

Another feature which draws attention in **Figs. 1a** and **1b** is that, out of many scattered localities of enhanced seismic activity and of relative seismic quiescence, just west of 110°E longitude, there is a remarkably silent zone, south off Java. This seismically quiet zone is about 75 km in width and trends almost N–S from the trench to the inland Java (**Figs. 1a** and **1b**). Although minor seismic activity (not visible in our data base) might be present here, absence of earthquake with magnitude $\geqq 4$, even in the inner thrust zone is certainly noteworthy. Relevantly, a buoyant oceanic high—the Roo Rise is subducting just south of this locality, and Curray et al. (1977)[8] also noticed, in their crustal refraction section, some irregularities here.

In **Fig. 2c** all events with magnitude $\geqq 6$ from the NOAA Data File have been plotted. **Fig. 2d** shows all the events with focal depth $\geqq 150$ km. We can clearly see that the number of large interplate events in the thrust zone off Sumatra is much greater than that for Java. This certainly reflects greater coupling at Sumatra. However, two earthquakes with magnitude $\geqq 8$ occurred south of Java, indicating local zones of high horizontal compressive stress.

For a better quantitative estimate of the seismic activity along the Sunda arc we prepared a strain release map for the entire region (numerical estimates are presented on maps in the Appendix, in four parts—A, B, C and D). We followed the method of Allen et al. (1965)[21]. Each $2° \times 2°$ square was divided into 25 small squares, each of $24' \times 24'$ dimension. The map area (denoted by the boundary of **Fig. 3**) was divided into 2850 such twentyfour minute squares, each of which was treated as a unit. The number of earthquakes occurring within a unit block was summed up for the entire period. The strain energy released by all the earthquakes in each $24' \times 24'$ square was calculated and converted into an equivalent number of earthquakes (N_4) of magnitude $M=4$. The equation used for this purpose is:

$$N_4 = 10^{0.75(M-4)}$$

where M is the magnitude of the corresponding earthquake. These numbers were plotted at the centre of each small square. The strain energy release map thus prepared is given in the Appendix (in four parts). In stead of contouring the values, we

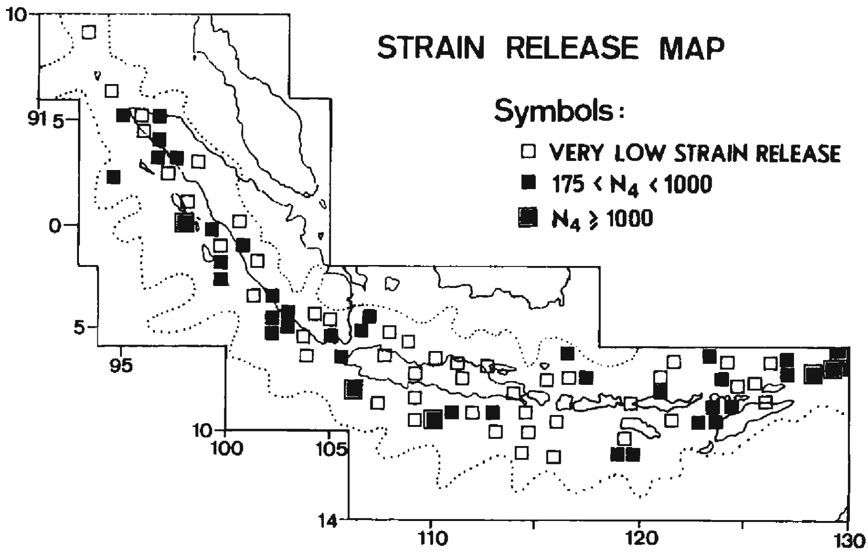

Fig. 3. Strain release map of the Sunda arc region. The dotted line demarcate the boundary of magnitude 4 earthquakes. Detailed strain release figures are presented in the Appendix.

plotted in **Fig. 3** the extreme values in symbols.

For computing the strain release figures, we used the NOAA (1900 to May, 1981) and the ISC (1971 to 1983, for events with at least 15 station reportings) Data Files. The accuracy of NOAA epicentral locations is not always very good. Also for the earlier years of this century, only the very large events have been reported. Further, the magnitude scale has also changed with time. For these difficulties, we carefully examined each and every event within a unit block. We checked with the recently developed catalogue (with some of the large events relocated and magnitudes homogeneized) of Newcomb and McCann (1987)[1] and minimized other data base incoherencies. For the smaller events the strain release is much less. For example, an earthquake of magnitude 8 releases strain energy equivalent to almost 1000 magnitude 4 earthquakes, for an event of magnitude 7 the equivalent number of magnitude 4 event is about 178, for magnitude 6 it is about 32, and so on. So missing of a few smaller events will change the strain release picture very little. For the large events our data base was more or less complete. The resulting strain release map is thus quite realistic.

In **Fig. 3** the hollow squares represent locations with very low strain release (say, less than 10 to 15 N_4). Areas within the dotted boundaries, but with no symbol are those of intermediate strain release. A very interesting pattern which emerges in **Fig. 3** (see also the Appendix) is that, adjacent to a very large strain release, there is almost always a zone of low strain release. This is more evident in Sumatra where more energy is being released seismically. Whenever a large earthquake occurs, a significant rupture accompanies. Tocher (1958)[22], Iida (1965)[23], Ambraseys and Tchalenko (1968)[24], Bonilla and Buchanan (1970)[25], and Slemmons (1977)[26], among many others, have studied the relationships between fault length and/or surface area and, magnitudes. Acharya (1979)[27] investigated the regional variations in the rupture-length to magnitude relationships. For Sunda arc no such empirical relationship is yet established. However, Newcomb and McCann (1987)[1] delineated from the intensity maps the rupture zones for some large events along the Sunda arc. It appears that many of the very low strain release localities demarcated in **Fig. 3** may be located within such rupture zones of very large events, and hence now being in a stage of strain accumulation, are quiet. As a few of these quiet zones may, however, be potential seismic gaps, more detailed and accurate spatio-temporal investigations are essential for understanding their true natures. Habermann et al. (1986)[28] explained the low seismicity at two regions south of Sumatra (note in **Fig. 3** at around 2°N, 97°.5E and 3°S, 100°.5E) to be possibly due to the interaction with and subduction below Sumatra of a migrating oceanic ridge (Investigator Ridge). The aseismicity of Java compared to Sumatra, excepting for two restricted spots (where very large strain energy was released in the past), is more prominent in our strain release map. In Lesser Sunda Islands, the strain release is again quite high, possibly in part due to the gradually increasing influence of the arc-continent collision. The very high strain release at the extreme right corner of **Fig. 3** is associated with the active subduction in the Banda arc.

Depth Distribution of Earthquakes

From ISC Data File, earthquake events between 1971 and 1983 with 15 or more station reportings were plotted in vertical sections of **Fig. 4** using the computer program of Ishikawa et al. (1985)[29]. The profile lines are shown in the upper part. All the previously reported features of the Benioff zone in this region are present in these updated depth sections.

We also constructed the vertical sections perpendicular to the profile lines and looked from the oceanic side to the island. For the last three profiles —MM′, NN′ and OO′, a notable feature could be traced, which is shown in **Fig. 5**. In this region the lack of continuity in seismicity between 300 and 500 km is well known since long time. However, as can be seen in **Fig. 5**, at around a depth range of 120 to 150 km, a zone of scarce seismicity exists. The feature is a consistent one. The density of earthquakes above and below this zone is somewhat greater. The feature does not appear to be just an artifact of inaccurate depth estimates. We suggest the possibility of a zone of stress transition at this depth. In our separate work (Ghose and Oike, in preparation), we have noticed that some of the earthquake focal mechanisms around this depth range show almost opposite orientations of the axes of maximum compressive stress, particularly in the eastern side. Isacks and Molner (1969)[30], at first, talked about the possible existence of a stress minima at an intermediate depth (at a different depth range and situation than the present feature). The present feature deserves attention. However, we must admit that our observation, at present,

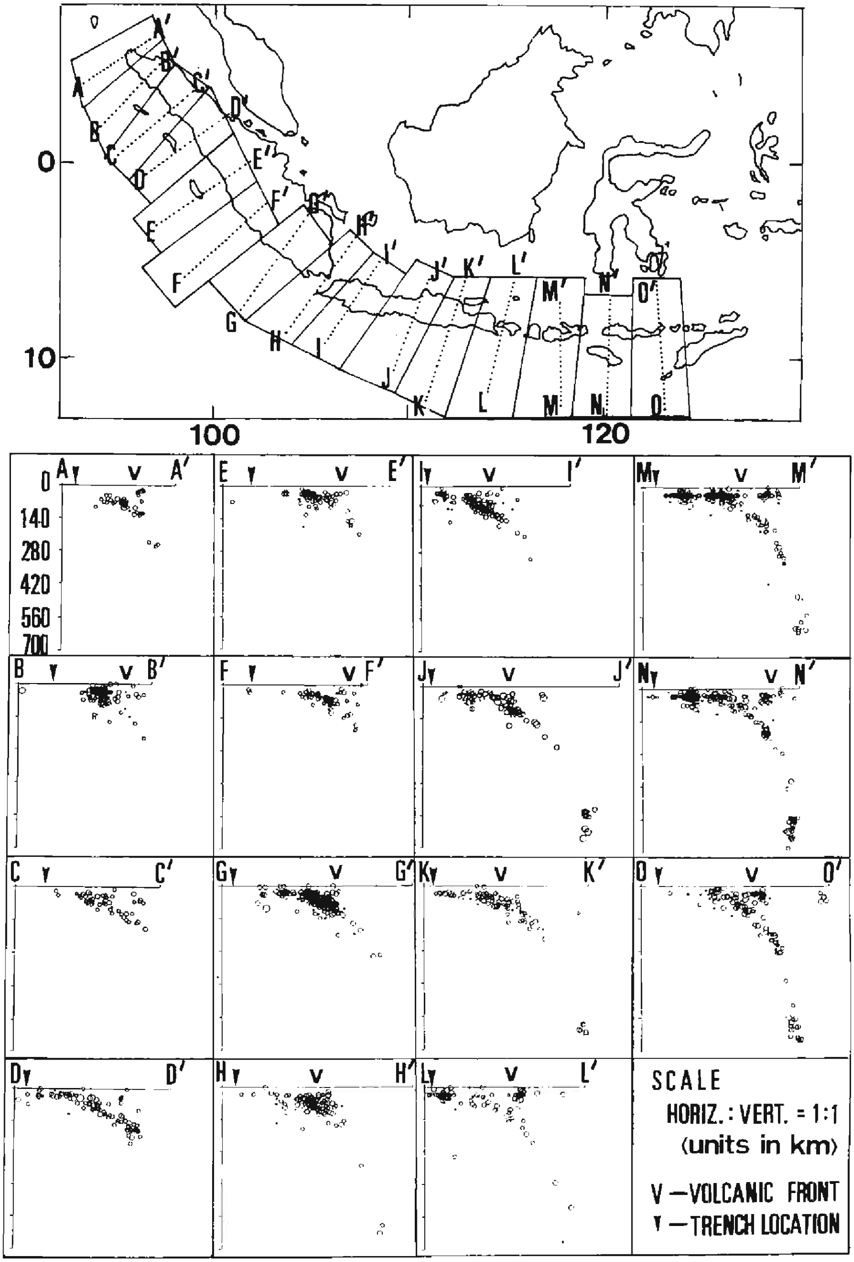

Fig. 4. Benioff zone structure along the Sunda arc. Earthquakes reported by 15 or more stations from the ISC Data File (1971–1983) are plotted against depth. All reported pP–P depths are used.

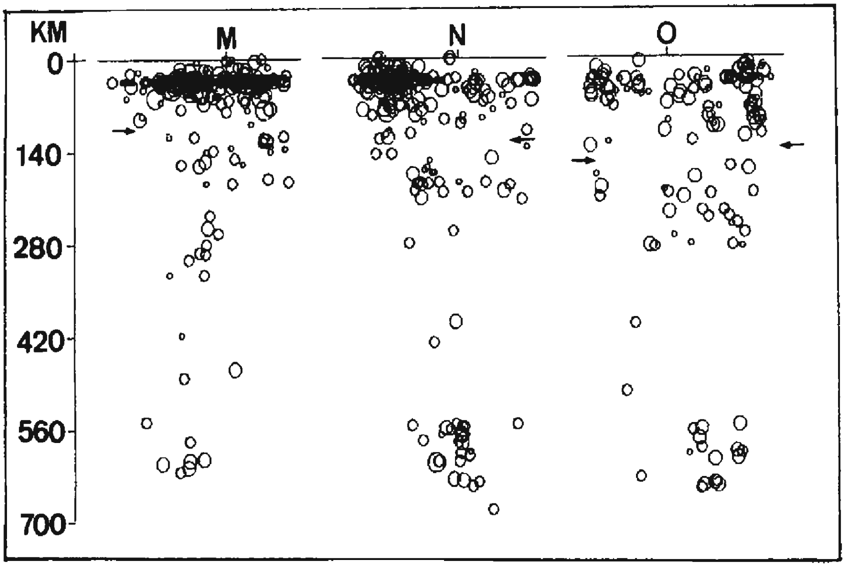

Fig. 5. Seismicity depth sections for the three easternmost blocks (with profiles MM′, NN′ and OO′) of Fig. 4. The depth distributions are while looking from the trench towards the islands, along the respective profile lines of Fig. 4. Positions of the southern ends of the profiles lines–M, N and O are shown. The scarce seismicity at an intermediate depth range is marked by the tiny arrows.

is a preliminary one which awaits further careful research.

Temporal Distribution of Seismicity

It is well known that the subduction dynamics, interplate coupling, as well as the resulting seismicity exhibit great variation along the length of the Sunda arc. Local heterogeneities, bathymetric undulations on the subducting oceanic plate and its age also vary significantly. Plate tectonic set ups also differ; at Sumatra, oblique subduction between two strongly coupled plates is believed to be occurring, causing transcurrent faulting and much of the slip seismically; at Java, it is normal subduction between two very weakly coupled plate segments, causing more aseismic slip; whereas at Lesser Sunda Islands, the effect of arc-continent collision is superposed on that of the subduction. In this situation, we were interested to see the patterns of temporal variation of seismicity in these three regions, in order to understand whether the locally varying subduction dynamics and tectonic factors dominate the pattern, or the general regional subductional stress. **Fig. 6** shows the temporal distribution of earthquakes with magnitude 6 or over of this century (1900–May, 1981). We can clearly see that the overall patterns of distribution of number (N) of events with magnitude $\geqq 6$ against time have a remarkable similarity for the three different tectonic provinces. Till 1935–40, the trend was rising. Then from 1935–40 to

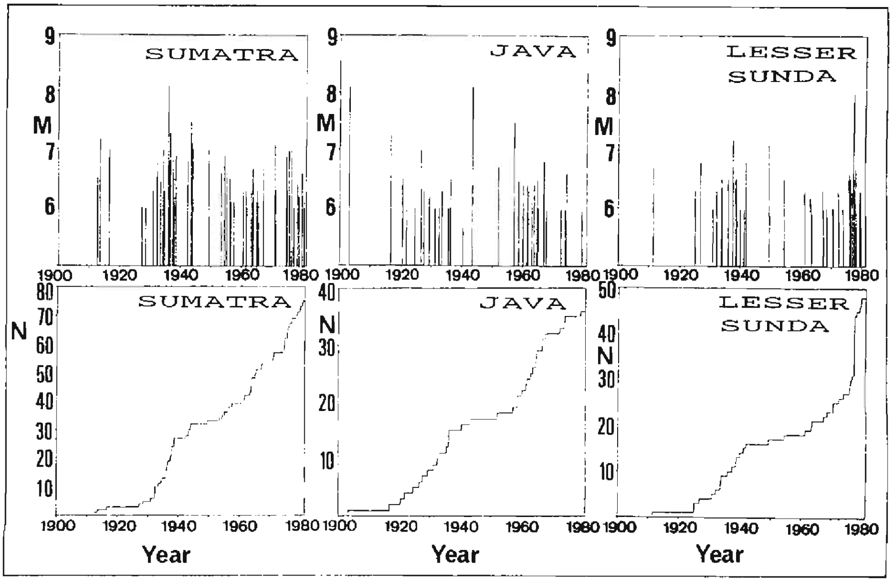

Fig. 6. Temporal distribution of seismicity in the Sunda arc region, using NOAA Data File (1900–May, 1981). Only the large events with magnitude ≥6 have been considered. In the upper part, magnitude is plotted against time, while in the lower figures, cummulative number of the events is plotted against time.

around 1960, for approximately 20 years, there were few large earthquakes in all of the three segments of Sunda arc. Subsequent to this till May, 1981, the seismicity was again high. (For Lesser Sunda Islands, the sharp rise around 1977 is obviously because of the large Sumba earthquake series.) From this marked similarity in the temporal pattern of seismicity, it is evident that the variation of the common tectonic force (viz., that due to the subduction of the Indian Ocean- Australian plate beneath the southeast Asia) with time, for all of the three segments of the Sunda arc was same, and that dictated the overall long period temporal pattern. Over this common long period fluctuation, the locally varying effects of subbduction dynamics, local plate tectonics and interplate coupling at the three individual segments are superposed, to give the ultimate picture (**Fig. 6**). It is possible to conclude that, although the causative geodynamic situations vary significantly in space, for the entire Sunda arc, the periods of increase or decrease in seismicity is largely space invariant. As if the varying local levels of seismicity mingles with a common long period seismicity fluctuation.

Seismicity and Altimetric Gravity Anomaly

In order to examine the seismicity of the Sunda arc in relation to the gravity anomaly, we made use of the satellite altimetric free air gravity anomaly data of Segawa and Matsumoto (1987)[31]. We traced the free air gravity anomaly map derived

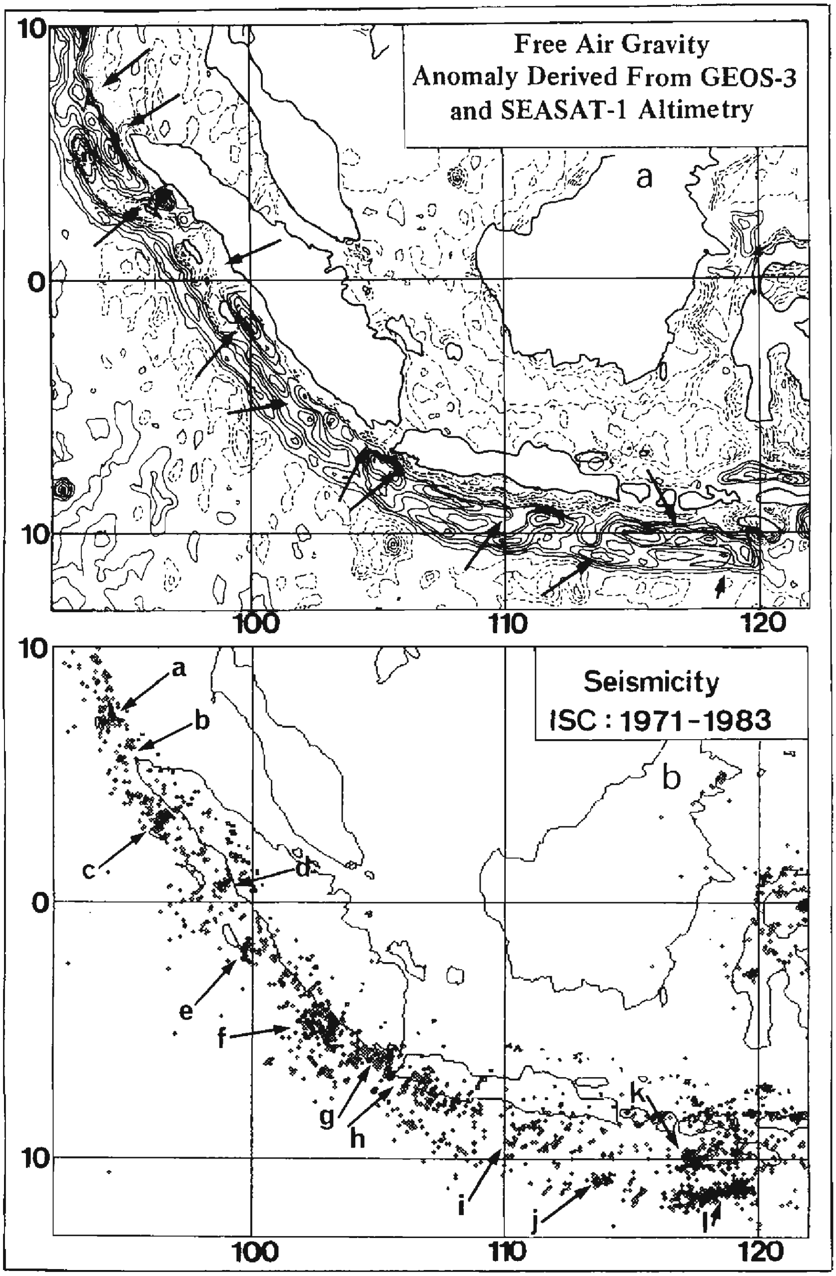

Fig. 7a. Free air gravity anomaly map of the Sunda arc region, as derived from satellite altimeter data (after Segawa and Matsumoto, 1987[31]). Solid and dashed contours represent negative and positive anomalies respectively. Arrows point to the locations (Fig. 7b) corresponding to high earthquake activity.

Fig. 7b. Seismicity distribution map of the Sunda arc (ISC Data File, 1971–1983, with events located by 15 or more stations), for comparing with gravity anomaly. Arrows show the patches of high seismicity.

from GEOS-3 and SEASAT-1 altimeter data (**Fig. 7a**). Segawa and Matsumoto (1987)[31] converted analytically the satellite altimeter data to free air gravity anomaly for the oceanic regions. Although differences exist between this alimetric gravity anomaly and true gravity anomaly particularly on seamounts and trenches, for preliminary investigation the accuracy is quite acceptable. In **Fig. 7**, the contour interval is of 20 mgal. Solid and dashed contours are respectively for negative and positive anomalies. (Although we did not draw the 0 mgal contour for the sake of simplicity of the map, the smallest radius solid line contour represents the negative minima). For comparision, in **Fig. 7b** we presented a plot of the ISC earthquake epicentres (1971–1983) located by 15 or more stations. The arrows show the zones of high earthquake frequency. The corresponding localities are also indicated by arrows in the free air gravity anomaly map. One can see a good conformity between the seismicity and the altimetric free air gravity anomaly in that, most of the earthquake clusters are located where the negative free air gravity anomaly contours are rather dense (i.e., deeper parts). Excepting a few (viz., d, g and h), for most of the seismicity clusters the matching is fairly good. Even if the possibilities of some earthquake mislocations and the deviation of the altimetric gravity anomaly from the true anomaly are taken into account, the picture does not appear to become very much different. Morphologically, the earthquakes tend to concentrate in the deeper regions of the inter-arc basin or its slope regions. We noticed, in vertical seismicity profiles taken parallel to the trench that, below these patches of earthquake clustering, the maximum depths of seismicity are greater compared to the surrounding. At the present moment, our evidences are not conclusive. However, the observation invites attention for future investigation.

Conclusions

Based on our present investigation of the spatio-temporal variations of seismicity the following conclusions could be reached:

(a) From the epicentral distribution maps, as well as the strain release map, we could notice that adjacent to the zones of high strain release, seismically quiet zones are often present. Some of these low strain release localities are possibly located within the rupture zones of the adjacent large events, and hence being in a stage of strain accumulation, are presently quiet. However, as the possibility of a few of these quiet zones to be potential seismic gaps certainly exists, more detailed and accurate spatio-temporal analysis is very necessary to ascertain their true natures.

(b) A careful inspection of the depth distribution of seismicity revealed that in a part of the eastern Sunda arc, possibly a zone of scarce seismicity at an intermediate depth exists. We discussed the implications, and recommended further investigations.

(c) The patterns of temporal variation of seismicity at the three different seismotectonic provinces of the Sunda arc—Sumatra, Java, and the Lesser Sunda Islands, were analysed. It could be observed that, although the causative geodynamic situations for seismicity vary significantly in space along the length of the arc, the period of increase or decrease in seismicity is largely space invariant. The locally differing levels of seismicity are superposed on the common background of long period seismicity fluctuation.

(d) Finally, a comparision of the locations of seismicity clustering at the Sunda arc with the contours of the altimetric free air gravity anomaly revealed some positive comformities. We recognised this observation as a preliminary one, for the purpose of inviting more devoted research attention in future.

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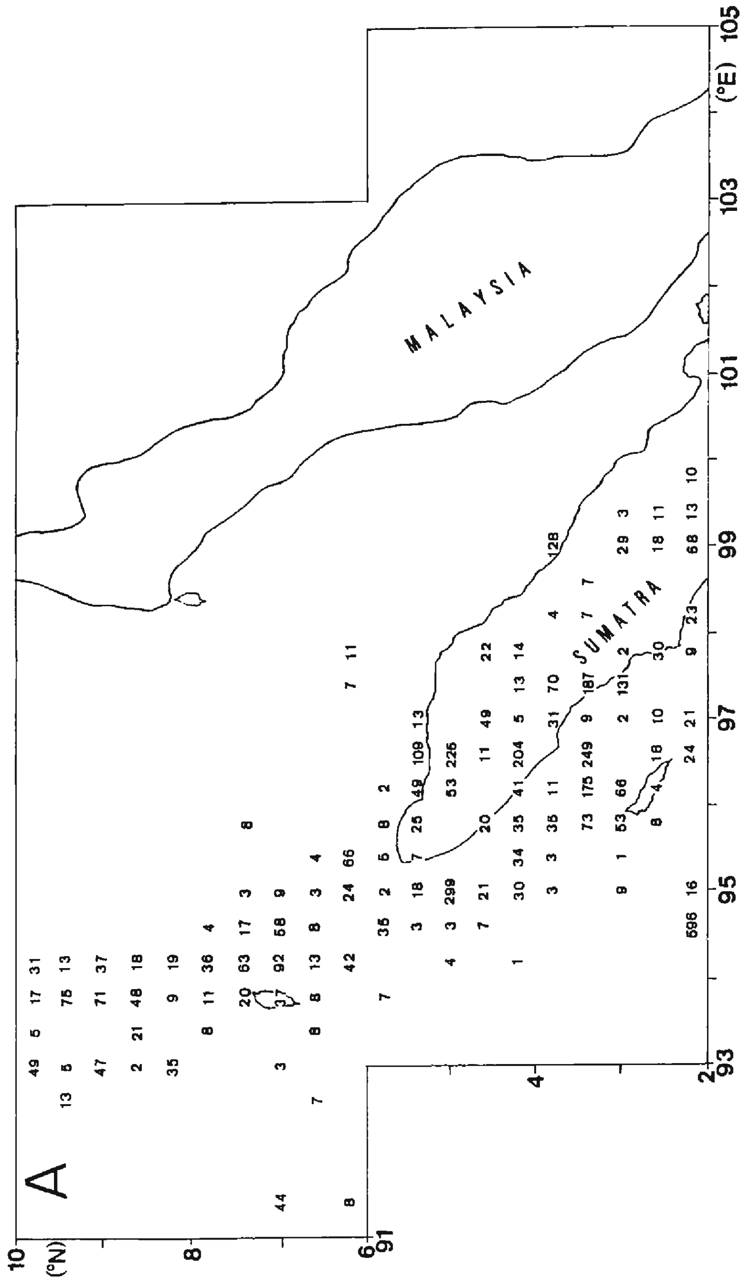
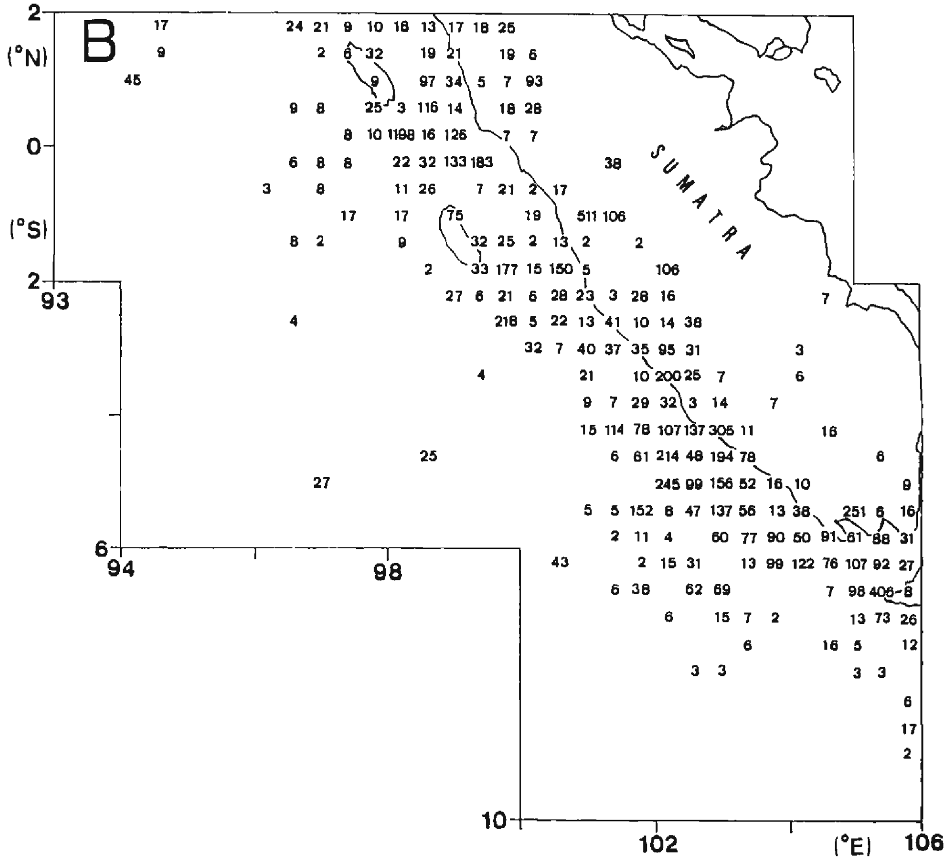
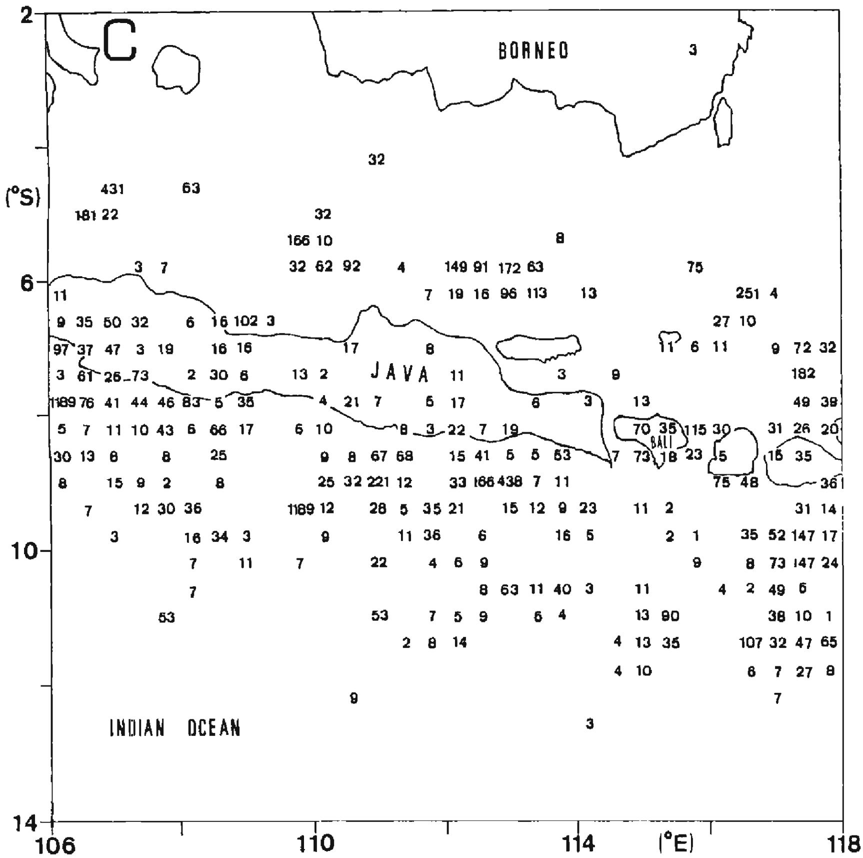
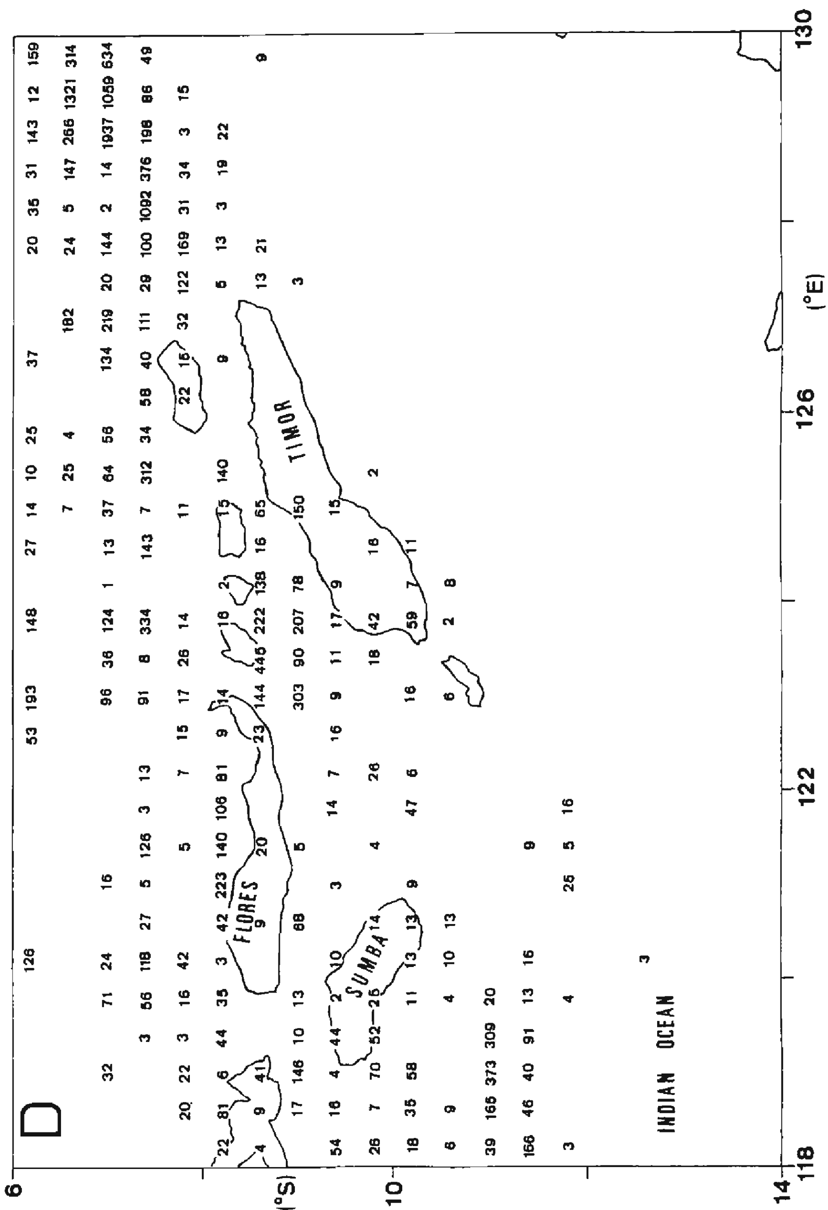
Appendix

Strain Release Map of the Sunda Arc Region
(presented in four parts—A, B, C and D)


A
MALAYSIA
SUMATRA
(°N)
(°E)


B
2
(°N)
0
(°S)
2
93
6
94
98
10
102
(°E)
106
SUMATRA


C
BORNEO
JAVA
BALI
INDIAN OCEAN
(°S)
2
6
10
14
106
110
114
(°E)
118


D
FLORES
SUMBA
TIMOR
INDIAN OCEAN
(°S)
6
10
14
118
122
126
130
(°E)